WINTERS IN WESTERN EUROPE [1]

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[Translated by W. W. Reed]

INTRODUCTION

In 1917, when my second study on the climate of western Europe was in press, M. J.-P. van der Stok urged the publication of the historical data that I had used in my research.

Evidently such a publication would be of some use. To assemble this information which related to the period extending from the distant past up to the present, and to a large part of Europe, was not an easy task and required much time. The comparison and critical examination of text, the necessary selection and methodical classification of the material occupied my time for several years. The histories of the abnormal winters are scattered through volumes or pamphlets which are very often not at hand for those who have need of them, and, in addition, isolated notes have a very limited value. In short, there did not exist any publication in which the character of the winters of western and central Europe was described in a few words, supported by the testimony of chroniclers and historians. This can be said without discounting at all the value of the important works of historians and meteorologists from Pilgram and Pfaff to Norlind, Speerschneider, and Vanderlinden, who for the most part have treated this matter only partially, limiting themselves to a rather short period or to a limited part of the climatic province.

The revision and discussion of the historical data necessitated a complete rehandling of the text although I have strictly limited myself to the climatic zone of western Europe when it was a matter of drawing conclusions and have occupied myself only with the winters, leaving out the other seasons, reports of floods, famines, etc., which are abundant in the old chronicles. It appeared to me rather evident that it was necessary to have recourse to an inversion of chronological order in order to profit as much as possible from historical information often vague and little worthy of belief. The modern thermometric observations alone constitute a safe basis for the methodical study of the meteorological indications drawn from the chronicles.

I resolved, then, to begin by assembling and discussing modern observations. It goes without saying that this entailed an enormous increase in work, so, in order not to delay indefinitely the publication that I had in view, I had to limit myself to meteorological observations made at representative stations in western Europe and the immediate vicinity. The great advantage of this method lies in the fact that it permits us to supplement considerably the historical data with the aid of results infinitely more precise and less arbitrary derived from the modern meteorological observations.

This comparison between modern observations and historical data is admissible only when one proceeds under the following assumptions: (1) In this part of the world the climate has not changed appreciably since the beginning of the Middle Ages, and (2) the variations in temperature have not been caused by periodicities with considerable amplitude. Arago in his study "on the thermometric state of the terrestrial globe" (Oeuvres T. VIII, p. 395) says: "Everything conspires to prove that the climates of Europe are in general in a state of equilibrium," and in the course of his study we have never encountered an argument tending to render the contrary opinion probable. Further, Angot (Ann. Bur. Centr. Met. Fr. 1897, B. 167) thus concludes his remarks on the variability of temperature:

> It is seen that at all of the stations the number of departures of a given order satisfies very exactly the theory of errors, which permits us to consider these departures as due to fortuitous causes. * * * These conclusions, it is to be understood, must be limited to the region studied in this work. [This region occupied the larger part of our "climatic province."]

In addition, J. von Hann sees no indication of a progressive change in temperature in Europe: "In none of the critically treated, long-period series of temperature records can there be demonstrated a continuous (noncyclic) change in annual temperature" (Hdb. d. Klimatologie, Bd. I, 3e Aufl. p. 348. *See also* Ekholm on the observations of Tycho Brahe, 1582–1597) compared with present climate (Hann, ibid., p. 347). The historical data that follow do not support at all the theory of some modern meteorologists that the climate of western Europe has probably become more severe and cold since about the year 1000.

As to the periodicities often conjectured, it is almost certain that they can not have the effect of overturning the distribution supposed here. However, to guard as much as possible against such an influence, we have taken the precaution to consider only multiples of the period of 89 years (1205–1916 equals 8×89) as the longest that can be taken into consideration. (*See* Easton, loc. cit. W. Köppen, Ann. d. Hydrogr. u. Marit. Meteor. XXV, 11, 1917, and Met. Zeits, XXXV, 3, 4; J.-P. van der Stok, Het Klimaat van Nederland. Tidjs. K. N. Aardrijksk. Genootschap XXXV, p. 348.)

The method indicated above agrees with the division of our publication into three parts.

The first part includes the modern thermometric observations, relatively homogeneous among themselves, and having a sufficient degree of accuracy; that is to say, after the middle of the 19th century. For the reason given above, I have made this series end with the winter of 1915–16.

The second part contains the old thermometric observations, made between the middle of the eighteenth and the middle of the nineteenth centuries; they are much inferior to modern observations, but still they can serve.

The third part contains the historical data from the most remote times to the present. However, the data previous to the year 760 and those after 1851 are to be regarded only as supplementary; they have a secondary interest only. On the other hand, the period comprised between the beginning of the thirteenth century and the middle of the eighteenth century has been treated carefully in order to be able to compare it with the scientific observations.

It is evident that the three epochs indicated here are not *rigorously* comparable.

Thus, in the third part of this work we have reproduced as information, even if somewhat fragmentary, all of the historical data available, selected and methodically

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arranged, but our chief conclusions relate only to the three periods as follows:

(*a*) 1205–1756, historical data;
(*b*) 1757–1851, old thermometric observations; and
(*c*) 1852–1916, modern thermometric observations.

For each winter of these seven centuries we have been able to compute a coefficient (often approximate) indicating the temperature of the (meteorological) winter (western Europe), whence there are easily derived general terms such as "severe winter," "warm winter," etc., which will have (henceforth) a value less subjective, their classification being based on the results obtained for winters since 1852, by the aid or relatively exact scientific observations. These winters could be arranged in the order of increase or decrease in temperature so that the severity or the mildness of each winter could be immediately judged from its place in the list. The simple inspection of another table suffices to make known whether a winter, after 1204, was about normal or more mild or more cold than ordinarily. It is needless to emphasize the provisional character of these indications at least for the winters whose temperature was rather near the normal, but there is reason to believe that they do not depart too much from the truth.

The arrangement of the "Register of remarkable winters" is explained later.

Thus the critical examination of the historical data and their comparison with scientific observations puts us in a position to give to the winters of past centuries a "coefficient of temperature," although the historical data do not relate to temperature alone, but to the humidity, snow, etc., of a winter, but it follows that the significance of the terms "mild winter," "severe winter," etc., as we employ them will never coincide exactly with the popular terms which are (besides) always vague, arbitrary, and impossible to define.

While the "coefficients" relate only to the (province) of western Europe the passages by old writers on *all* Europe (with the exception of eastern and southern regions) assembled here. The bibliography, which contains more than 500 publications, mentions the place where the report was written or the region to which the information relates, which is indispensable in judging their extent and value.

The results obtained have nothing of definiteness. In the course of this long drawn out work we have had many times occasion (opportunity) to determine the lack of precision in certain historical data and even in certain scientific observations. On the other hand we are convinced that the historical data extending over more than 10 centuries, are often—for the *abnormal* winters—remarkably exact; they constitute a unique and valuable source of climatology.

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CHOICE OF METEOROLOGICAL ELEMENTS

1. The monthly means. These constitute in our opinion the best basis for determining the character of the winter on the condition of having been determined with much care. However, in themselves they are insufficient for in an abnormal winter, for example, with December well below and February well above the normal, it often happens that these anomalies disappear in the final figures.

2. Days with frost. These constitute an element noted for centuries, but which is very variable according to local conditions.

3. Days without thaw (ice days) are important for the very cold winters, but useless for the classification of moderate or mild winters.

4. Days with maximum $-10°$ C. or below. These very cold days complete the indications given under (3). (The same remark applies.)

5. The absolute minimum of a winter is often found in the old publications, but it gives no idea of the character (more or less cold) of the season and it does not satisfy the needs of modern methods.

6. $1/2\ (a+b)$, a denoting the sum of the minima, b that of the maxima of temperature in a series of at least 14 days when the temperature fell below zero.

7. The sum of the negative means for the days from November to April. (Hellmann.)

All of these elements, alone or combined, can have a certain usefulness; for the particular purpose that we have before us we have believed it (advantageous) to make use of Nos. 1, 2, 3, and 4, supplementing these data with:

8. The mean of the three extreme minima in the different months of the same winter, November to March.

Thus in the present work use has been of the—

Monthly mean.
Number of frost days.
Number of ice days.
Number of very cold days.
Mean of three minima.

Discussion of the observations, winters of 1852–1916.—For all of the winters and for the nine selected stations, Bremen, Uccle, De Bilt, Paris (St. M.), Greenwich, Angers, Toulouse, Lyon, and Strasburg, there has been calculated the departure from the normal (d), the probable error (e) and the value d/e, that is the departure expressed in multiple of the probable error.

The other meteorological elements (outside of mean temperature) have been combined to derive a "coefficient of intensity." With the exception of the series of three minima it has not been possible to apply the rigorous method followed for the monthly means, this stands out from the simple inspection, for example, of the series of ice days for Toulouse or Angers.

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After having calculated in this manner a coefficient for each meteorological element it was necessary to combine these coefficients in a proper manner to set forth the greater or less intensity of the cold of any given winter. In general we have given the weight of 2 to the series of three minima because it appears to us to offer the best measure of the greater or lesser intensity of cold from November to March and because this element can be obtained almost without break for all of the stations; the other coefficients, frost days, ice days, very cold days ($-10°$ C.) have the weight 1, in the case where one or several of the elements were lacking, we were content to use the others. The combination of the elements here named for the coefficient of intensity, that combined with equal weight with the mean coefficient (monthly mean) gives the coefficient of temperature, which we regard as the best characterization of the winter temperature.

Results.—It would take too much space if we gave *in extenso* all the series that have served to establish the results, according to the method explained above, for the nine stations 1852–1916 and the five stations 1757–1851. An appendix contains the principal series.

Outside of the historical register of remarkable winters the principal results of the present work are summarized in six tables (following the register):

Table 1 (1852–1916).—Coefficients of temperature: This table gives for the stations Bremen, Uccle, etc.: (*a*) The mean coefficient (monthly mean) for each winter, (*b*) the coefficient of intensity, (*c*) the temperature coefficient. For each winter the temperature coefficients of all of the stations have served for the derivation of a temperature coefficient (general) for the climatic province. (Weights: Paris, 4; Angers, Lyons, De Bilt, 3; Uccle, Bremen, 2; Strasburg, Toulouse, Greenwich, 1.)

Table 2 (1852–1916).—Classification of winters: This table shows the 65 winters in the order of decreasing temperature according to the temperature coefficient for the climatic province. (Table 1, last column.) It gives general indications, "mild winter," "severe winter," etc., according to the principles of our classification.

Table 3 (1757–1851).—Temperature coefficients: This table furnishes the same elements as Table 1, taken from the observations of Zwanenburg, Paris, Greenwich, Toulouse, and Basel. For the general temperature coefficients there were given weights as follows: 3, 3, 1, 1, 2.

Table 4 (1757–1916).—The winters of 1757–1916 classified according to (increasing) temperature: Order numbers, coefficient of temperature, general characteristic.

In the period we count 1 "great winter," 5 very severe, 12 severe, 23 cold, 17 rather cold normal (winters) 42 normal, 21 rather moderate normal winters, 30 moderate, 6 mild, 3 very mild.

Table 5 (1265–1756).—The winters 1205–1756 classified according to their (increasing) temperature: Classification of these winters according to historical information. There have been entered in this list only the winters considered abnormal. There has been assigned to these winters only the following (approximate) temperature coefficients (see p. 10) 4, 10, 17, 21, 25, 28, 31, 34, 36, 38, 42, *54*, 60, 63, 66, 70, 74, 79, 82, 90. The coefficient *54* has been given to 257 winters where there is found no mention of a certain (character) and all of which have been considered normal, there is very great probability that these winters did not depart much from the normal; a certain number of these winters were probably "rather moderate."

In this period of 552 years we count 4 "great winters," 13 very severe, 46 severe, 74 cold, 43 rather cold normal winters, 257 normal or rather moderate, 87 moderate, 24 mild, and 4 very mild.

Table 6.—Chronological list of winters from 1205 to 1916, and some remarkable winters prior to 1205, with their temperature coefficients (approximate up to 1756) and a general characterization. (Data prior to 764 very uncertain.) In the characterization of the winters 1757–1851 preference is given to historical evidence (coefficients in parentheses), in case the difference between the scientific result and the popular impression is important; after 1851 we have confined ourselves to the scientific observations.

This list, based on historical data, brought into agreement with modern scientific observations, show at a glance the character of all remarkable winters mentioned in the history of western Europe, and for a period of seven centuries the approximate character of all other winters, even those which departed but little from the normal.

Doctor Eaton, as indicated in his foreword, now presents a summary of the great mass of historical data used in his previous researches which were published under the following named titles: Oscillations of Solar Activity and the Climate Proc. R. Ac. Sci., Amsterdam, November 1904 and May 1905; and "Periodicity of Winter Temperatures in Western Europe," published by the same institution in August, 1918.

The essentials, so far as given in the records, covering the winters between 396 B. C. and 1928 A. D. are summarized under the caption "Register of Remarkable Winters," the text of which takes up 131 of the total of 210 pages in the work. The tables which give in brief form the results of his studies are as follows:

Table I.—Coefficients of temperature winters of 1852–1916.
Table II.—Classification of winters of 1852–1916.
Table III.—Coefficients of temperature winters of 1757–1851.
Table IV.—The winters of 1757–1916 (classed according to their temperature, increasing order).
Table V.—Classification of winters 1205–1756 (classed according to increasing order of temperature as given in historical records).
Table VI.—Chronological list of winters from 1205 to 1916 and remarkable winters before 1205 with their coefficients of temperature, approximate to 1756–(Characteristics very uncertain before 764).

In an appendix the values of $\frac{d}{e}$ which served to determine the "coefficient moyen" for each of the nine stations for the period 1852–1916 are given.

The outstanding winters in western Europe during the ninteenth century according to Doctor Eaton's classification were:

1830 great winter in the sense of extreme cold.
1880 very cold.
1891 very cold.
1834 very warm.

The correspondence between the winters of western Europe and those of eastern United States is not close; thus 1830, the winter of greatest cold in more than a century in western Europe, was not unusually cold in eastern United States, nor was the winter of 1834 unusually warm. Nevertheless, Doctor Eaton's work will serve as a foundation on which the synchronism or lack of it in temperature fluctuations the world over may quickly and easily be made.—*A. J. H.*